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# Development of Visual Programming Techniques to Integrate Theoretical Modeling into the Scientific Planning and Instrument Operations Environment of ISTP

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## Final Report

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**ORIGINAL CONTAINS  
COLOR ILLUSTRATIONS**

(NASA-CR-192707) DEVELOPMENT OF  
VISUAL PROGRAMMING TECHNIQUES TO  
INTEGRATE THEORETICAL MODELING INTO  
THE SCIENTIFIC PLANNING AND  
INSTRUMENT OPERATIONS ENVIRONMENT  
OF ISTP Final Report (Maryland  
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## **Final Report:**

# ***Development of Visual Programming Techniques to Integrate Theoretical Modeling into the Scientific Planning and Instrument Operations Environment of ISTP***

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The goal of this project is to investigate the use of visualization software based on the visual programming and data-flow paradigms to meet the needs of the SPOF and through it the ISTP science community. Specific needs we address include science planning, data interpretation, comparisons of data with simulation and model results, and data acquisition. Our accomplishments during the twelve month grant period are discussed below.

## **2 Accomplishments**

During the first six months of the project we evaluated both AVS and apE as candidates for the multi-platform visualization environment on which to base our development. We selected AVS as the primary package, as described in our six-month progress report. Using AVS, we developed three dimensional displays of satellite trajectories, empirical models of magnetospheric boundaries and fields, and field and plasma results from empirical and global MHD models. We began exploring mechanisms to allow our system to communicate with other packages,

thereby allowing users to incorporate capabilities of those packages and continue to make use of tools they have developed themselves.

During the second six months of the project we refined our AVS tools, developed a number of data-comparison capabilities via inter-application communication with AVS and PV-Wave, incorporated additional ephemeris and key parameter data sets into our displays, implemented modules to read the GGS CDF files directly, and combined all these techniques into several prototype systems. We have shown our work to the ISTEP community through live demonstrations at Science Working Group Meetings, and videotaped animations for distribution. Several GGS and CLUSTER investigators have expressed serious interest in it.

## **2.1 AVS selected as primary package**

We have determined that AVS is the software package to pursue. We found AVS easier to use with a better, more coherent user interface. It has a more sophisticated data flow model based on shared memory and socket communication; apE used simple pipes for data flow. Finally development of new functions in AVS is significantly easier.

In addition this choice was also determined by the evolution of the organizations behind AVS and apE. apE changed from an academic package to a commercial one marketed by Taraviscuals, Inc. This change eliminated a major advantage of apE, source code availability for a nominal charge. In a more general

sense, the change highlighted the weaknesses of an academically-based system; the inability of the staff at the Ohio Supercomputer Center, with a typically limited budget, to cope with the large volume of users needing support for apE, a quite complex package.

Equally dramatic institutional changes occurred regarding AVS, but in our opinion these actually left AVS in a stronger position. AVS was originally developed by Stellar Computer for their line of super-minicomputers. After merging with Ardent Computer, the new Stardent Computer decided, under customer pressure, to port and/or license AVS for other Unix systems, including DEC, SUN, HP, and IBM. This decision made AVS a viable candidate for our study. Subsequently, Stardent Computer has folded as a hardware manufacturer, spawning AVS, Inc. as a software company to develop and support AVS. Since then three new versions of AVS , 3.0, 4.0, and 5.0, have been released and ported to over 20 more platforms, including supercomputer-class machines from six manufacturers.

AVS, Inc. has also established a strong user support group as well as a vendor AVS consortium. Vendors who are currently members of the AVS consortium include: AVS Inc., Convex, DEC, HP, IBM, Kubota Pacific, and Sun. Through support by the AVS consortium and the International AVS Users Group, an International AVS Center has been established at the North Carolina Supercomputing Center, where approximately 500 user-donated modules are available via any-

mous ftp. The IAUG also holds an annual conference. Thus we feel AVS has matured into a strong multi-platform visualization package with excellent user support.

## 2.2 Display of Magnetospheric Boundaries

Working with Mauricio Peredo, we have developed an AVS module to display the empirical models for the magnetospheric boundary layers used by the SSC software of the NSSDC to define regions of the magnetosphere for science project planning. These are: the bow shock model of Fairfield [Fairfield, 1971], magnetopause model of Sibeck [Sibeck *et al.*, 1991], and the neutral sheet model of Fairfield [Fairfield, 1971]. This module allows the staff of the SPOF to display 3D surfaces of these boundaries with interactive control over the parameters of the models defining the surfaces.

At the suggestion of Dan Baker and Ed Hones, we have enhanced the original modules to display conceptually the so-called Windssock effect. The new module models the effect of a change in the solar wind direction on the magnetospheric boundary layers as the change propagates down the magnetosphere. The location, angle, and extent of the disturbance can be controlled interactively, producing an animated 3D display of the predicted effect. While this display is a simple model of the Windssock effect, animations of the model can stimulate serious thought.

## 2.3 Display of Magnetic Fieldlines

We have successfully ported to our system Tsyganenko's implementation of his 1989 magnetic field model [Tsyganenko, 1989] and reimplemented it as an AVS module. This module allows universal-time-coordinated 3D display of fieldlines traced from one or more seed points. We have developed displays with many fieldlines selected to illustrate large scale features of the Earth's magnetic field.

We have also developed the ability to trace the magnetic flux tubes passing through spacecraft positions down to the Earth's surface using the Tsyganenko 89 field model; other field models or MHD simulation results can be easily substituted. The position of the corresponding footprints of the flux tubes can be seen in relation to the approximate fields-of-view of the ground stations of the Canopus array in Canada, shown as red disks. The Earth is represented as a sphere with continental outlines. The displays can be easily animated in time, so that the system is animated over time, showing magnetic conjunctions of the spacecraft and ground stations as they occur. For Example, figure 1 shows the footprint of the flux tube passing through IMP-8 with the Canopus stations. This prototype demonstrates the usefulness of such systems for science planning activities of the SPOF.

## 2.4 Display of Spacecraft Trajectories

We have developed a set of AVS modules that display in 3D the position at a given time and its trajectory before and following that time of a spacecraft using data from NSSDC ephemeris files. The positions of several spacecraft can be displayed using multiple copies of these modules. Because they are all linked to a common universal time variable, their relative positions are accurate. This time variable can be easily animated, creating an animation of the motion of sets of spacecraft.

Because of the modular nature of AVS, the boundary layer and field line displays can be easily added to the spacecraft trajectory displays. Thus we can follow the synchronized motion of several spacecraft in relation to the bow shock, magnetopause and neutral sheet. Using the base functions of AVS, the combined display can be arbitrarily and interactive rotated, translated, and zoomed (in and out). We obtained additional ephemeris data from NASA on other spacecraft and the moon. These can be displayed concurrently and in any combination, as for example that shown in figure 2.

## 2.5 Display of MHD Simulation

We have explored using AVS to display the results of the MHD code [Lyon *et al.*, 1987] used by the University of Maryland Theory investigation to globally model the magnetosphere. Our purpose is to develop ways of making the model

results easily available and accessible to all the ISTP investigators. We have developed AVS applications that read in the MHD results, display “cut planes”, isosurfaces, and vector (arrow) plots of any of the MHD variables. Furthermore we have developed an AVS module that will interpolate the MHD data, defined in a volume, onto an arbitrary set of points. This module allows us to interpolate the MHD results onto a spacecraft trajectory, allowing direct comparison of the MHD results with the *in situ* data collected along that trajectory. We have expanded our capabilities for quickly producing such direct comparisons of data and simulation results by communicating with other packages, such as PV-Wave or IDL, as discussed in the next section.

## 2.6 Data Display through Inter-Application Communication

We have chosen to take advantage of the simple yet powerful graphics capabilities of PV-Wave to display actual spacecraft data in combination with 3D display of spacecraft trajectories. This required the development of AVS modules that exchange data and communicate with PV-Wave. PV-Wave can produce stacked line plots suitable to display the time series data collected by spacecraft instruments. In figure 3 we show magnetic field and plasma data from IMP-8 during an outbound pass from the magnetosphere to the magnetosheath and out into the solar wind. The plots displays are synchronized with the complete 3D display of the satellite position, trajectory, and the empirical bow-shock,



magnetosphere, and neutral sheet surfaces. Our latest modules use shared-memory for efficient data transmission between PV-Wave and AVS, and allow arbitrary operations on the data within PV-Wave

When combined with the module to interpolate MHD results along the same trajectory, the display of stacked line plots allows the comparison of simulation results with the observed data measured by the spacecraft, or comparison of results from different models or numerical simulations, in order to compare models and investigate differences.

## **2.7 Direct Data Import**

For all of the above applications, the ability to input ISTP and NSSDC data into AVS has been key. We have found the extensible nature of AVS has enabled us to easily develop a number of modules to read SSC and CDHF data directly into our AVS networks. For example, we can now read Key Parameter data from CDF files extracted from the ISTP Central Data Handling Facility. This also required incorporation of capabilities for handling various spacial coordinate systems and differing universal time representations commonly encountered in data from multiple sources within NASA and the researchers. In addition to simplicity and improved speed, the ability to read the appropriate CDFs directly into the AVS network suggests that in future we can take advantage of AVS's remote module mechanism to obtain data directly from remote sites over high-

speed networks.

### 3 Demonstrations

We have demonstrated the new functions and tools we have developed for AVS at several SWG meetings. The real-time demonstrations using Maryland workstations have generated significant and increasing interest from the ISTP community. During the January GGS SWG meeting at NASA GSFC, we hosted a site visit to the Advanced Visualization Laboratory by members of the ISTP mission, including NASA Goddard personnel and investigators from UCSD, Lindau, Germany, and France. While it would be unrealistic to *enforce* a graphic standard for the project, we hope that the SWG will see the value of these tools, and the ease of developing new ones within AVS.

Demonstrations of the work have been well received at other conferences, including the 3rd Huntsville Workshop on Magnetospheric Plasma Models.

In addition to these demonstrations, at the request of the Project we assisted in supporting the summer IACG meeting in Airlee, Va. We provided computers, technical support, and simulation results in order to show the mission planning and data analysis tools we are developing in collaboration with the SPOF. We thus helped in the planning of the IACG campaigns by displaying in 3D "on the fly" the positions of Interball and other spacecraft for the periods being considered.

In addition to live demonstrations, we have produced video animations on space science data analysis and mission planning tools. These were shown and very well received at the January GGS SWG meeting at NASA GSFC. In response to many requests, we produced a revised video with voice-over for reproduction and distribution to NASA researchers.

## References

- Fairfield, D., Average and unusual locations of the earth's magnetopause and bow shock, *J. Geophys. Res.*, 76, 6700, 1971.
- Fairfield, D., A statistical determination of the shape and position of the geomagnetic neutral sheet, *J. Geophys. Res.*, 85, 775, 1980.
- Goodrich, C., R. Kulkarni, D. McNabb, and M. Peredo, Interactive Tools for ISTEP: Science Planning and Data Analysis, *Video tape: AVL and NASA/GSFC*, 8 minutes, February, 1993.
- Lyon, J. G., J. A. Fedder, and J. D. Huba, The Effect of Different Resistivity Models on Magnetotail Dynamics, *J. Geophys. Res.*, 91, 8057, 1986.
- Sibeck, D., R. Lopez, and E. Roelof, Solar Wind control of the magnetopause shape, location and motion, *J. Geophys. Res.*, 96, 5489, 1991.
- Tsyganenko, N. A., On the Redistribution of the Magnetic Field and Plasma in the Near Nightside Magnetosphere during a Substorm Growth Phase, *Planet. Space Sci.*, 37, 183, 1989

## **Appendix B Figure Captions**

Figure 1. Magnetic conjunction of flux tube through IMP-8 with Canopus station, Tsyganenko 1989 model.

Figure 2. Spacecraft and moon trajectories with magnetospheric boundary layer (half) surfaces: bow shock, magnetosphere, neutral sheet.

Figure 3. IMP-8 magnetic field and plasma data on outbound pass from magnetosphere to magnetosheath, plotted by PV-Wave/AVS module.

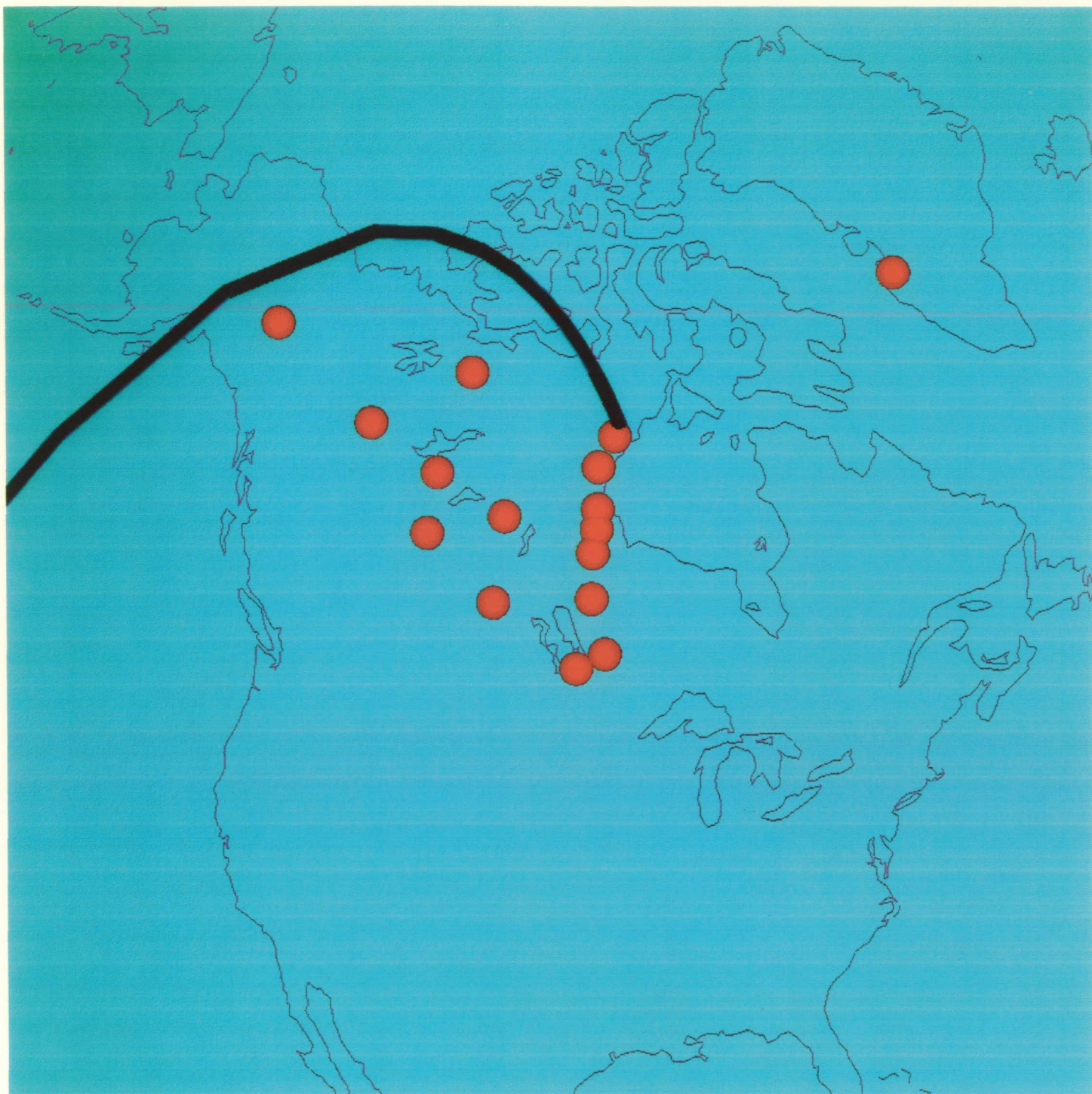


Figure 1

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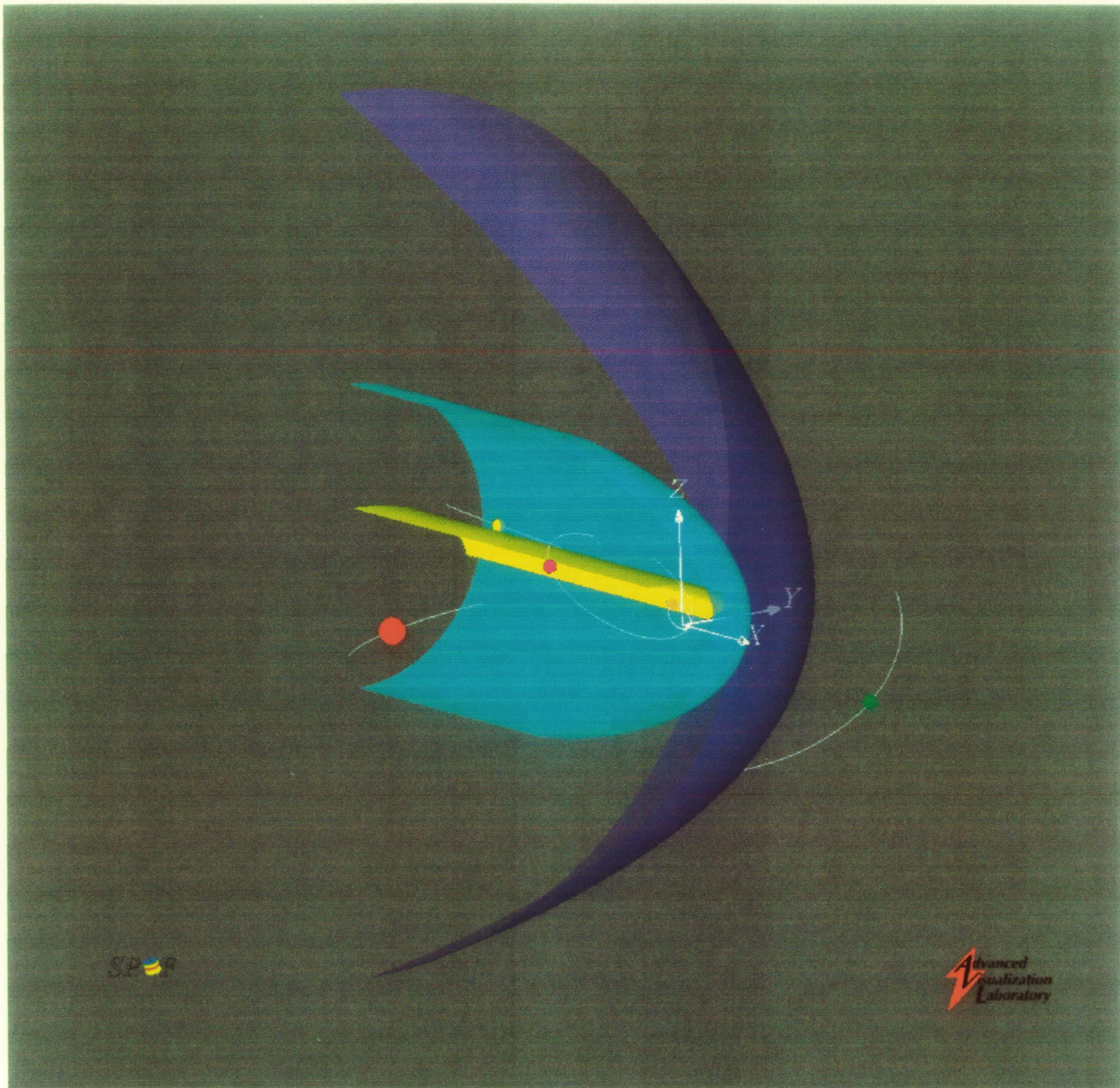


Figure 2

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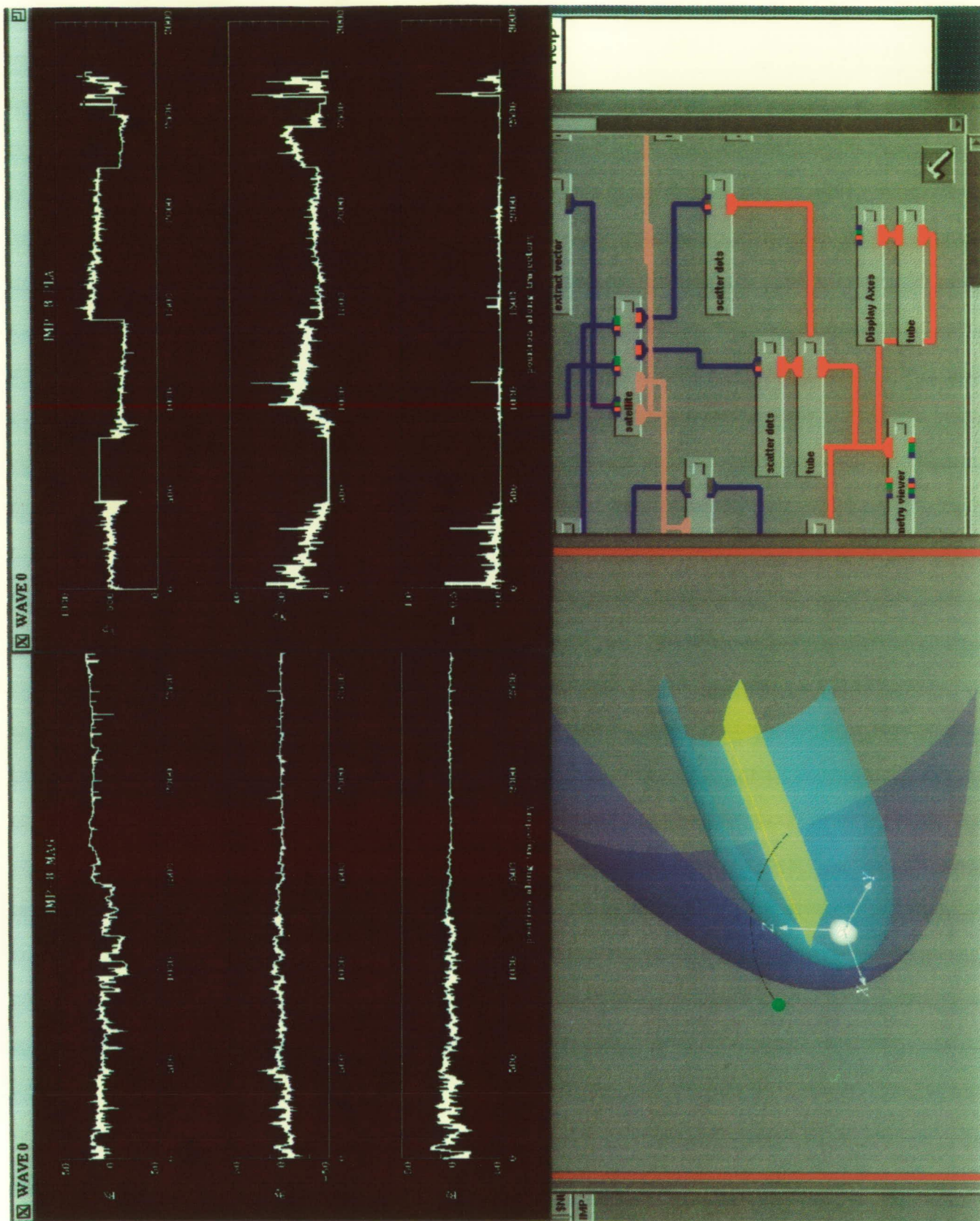


Figure 3

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